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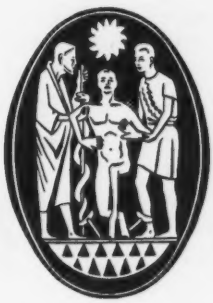

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ORIGINAL PAPER

EFFECT OF HIGH-FREQUENCY CURRENTS AND INFRA-RED RAYS ON THE CIRCULATION OF THE LOWER LIMB IN MAN

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HEAT in various forms is used extensively in therapeutics, but the reasons for its beneficial action are uncertain. Among the factors which may be involved are changes in blood flow and modification of metabolic or other processes or alteration of the function of nerves and nerve-endings.

From ancient times to the present heat has been used as a therapeutic agent, though the methods of application have varied from natural sources, such as the sun or thermal springs, to the present electrical methods, which include deep heating by high-frequency currents and superficial heating by infra-red rays.

This paper describes a study of the effect of heat on the circulation of the lower limb in man, with particular reference to distinguishing between its action on superficial and deep blood flow. For the purposes of the study the method described by Kety (1949), which is based on the clearance of locally injected radioactive sodium (^{24}Na) and is an indication of blood flow at capillary level, was used.

MATERIAL AND METHOD

The subjects studied were in-patients at the Devonshire Royal Hospital, Buxton, or out-patients at King's College Hospital, London, of both sexes and aged 19–60 years. None had any evidence of peripheral vascular disease or abnormal knee-joints, but were receiving treatment for other disorders.

The subject was rested on a couch for at least 30 minutes, with the legs horizontal and supported in plaster casts to prevent leg movements. The room temperature remained constant during each observation, but varied between

19° and 22° C. on different days. Skin-temperature measurements were made before and after all experiments, also during the experiment when practicable, using skin thermocouples connected to a Cambridge skin thermometer. The sites of the thermocouples depended on the experimental procedure. The Cambridge skin thermometer was calibrated against a standard mercurial thermometer before each experiment and adjusted to the relevant room temperature. In separate experiments deep muscle and joint temperature was measured with a needle thermocouple to ascertain temperature changes, but these were not included in the blood-flow studies as the presence of a needle might influence the local blood flow, also it would not be comfortable during such procedures as exercises. In addition, when short-wave diathermy was applied, any metal, such as a needle, would have to be removed before and reinserted after heating to avoid local tissue burning, and this reinsertion might influence blood flow.

Between 0·1 and 0·5 ml. of isotonic saline, containing 5–10 microcuries of ^{24}Na, was injected rapidly into the tissue to be studied through a 26-gauge hypodermic needle with the usual aseptic precautions. The skin injections were subcutaneous and the muscle injections were to a depth of 2·5–3 cm. The intra-articular injections of the knee were retropatellar from behind the medial border. No local analgesic was used, but little pain was experienced.

An unshielded scintillation counter was placed at a fixed distance from the injection site, and rates of clearance were recorded at one-minute intervals on a ratemeter. In some experiments, such as on the knee-joint, a counter was placed at each side of the joint and recordings were made from two ratemeters, to demonstrate any shift of ^{24}Na in the joint after the injection and to compensate for any movement which may have taken place. No major difference was found in the simultaneous recordings, though the composite graph gave a more "smoothed" effect than each individual graph, facilitating the calculation of the slope of the graph (Fig. 1).

The experiments were controlled by injecting the opposite limb at a similar site, and studying the clearance rate at the same time. To prevent any radiation scatter the limbs were separated by a wall of 2-inch-thick lead blocks.

The initial counting rate on each ratemeter was about 1,000 pulses per second, and this was recorded until the background level was reached; this value minus the final background, with correction for radioactive decay, was plotted semilogarithmically against time for each counter, and in the double-counter experiments a composite graph was also plotted. From the graphs the clearance constant K was found where

$$K = \frac{\log C1 - \log C2}{0{\cdot}4343\,(t2 - t1)}$$

where C1 and C2 are the counting rates at times $t1$ and $t2$ respectively, and $0{\cdot}4343 = \log e$.

In a series of preliminary experiments it was found that for 5–10 minutes after the injection the clearance rate was a little erratic, then settled down to a steady rate depending on the local circulation. In all the experiments the first few minutes of clearance was ignored and a steady clearance rate (K1) was followed for a period of 10–20 minutes before any experimental procedure was performed, so that a basic clearance rate could be established for comparison with subsequent alterations.

The clearance constant during the period of heat application is expressed as K2, but in some experiments this was not established owing to the unevenness of the clearance rate, or because the period was too short, or in some short-wave experiments, especially on the knee-joint, because of the need to move the scintillation counters. After this heating period the clearance constant is expressed as K3, and this covered 10–30 minutes. A change of clearance rate of 10% or over is considered significant throughout.

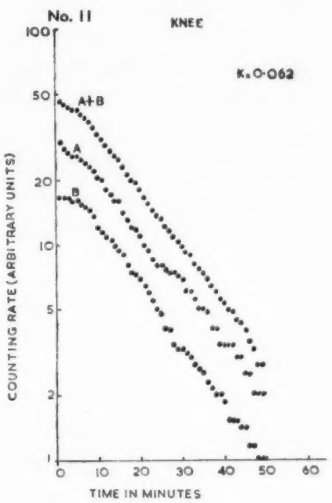

FIG. 1.—To show composite graph A+B, with graphs A and B representing individual counts when two counters are placed on opposite sides of a knee-joint and the clearance rate of ^{24}Na is measured.

EXPERIMENTS

1. SUPERFICIAL HEATING

The effect of heating the lower limb by infra-red radiation was determined by placing a 1,000-watt luminous generator (Hanovia Ltd.) at a distance of approximately 30 inches from the area to be heated. Skin temperature was measured by a shielded skin thermocouple connected to a Cambridge skin thermometer. The temperature was governed by skin tolerance, so that a sensation of comfortable heat was experienced.

The technique was the same as that described earlier, a preliminary period being followed by heating for 20 minutes. The heater was switched on and warmed up before being directed on to the area to be heated. The opposite limb was shielded by a screen.

The areas studied were the skin of the thigh and the underlying muscle, the knee-joint, the anterior tibial muscle, and in most experiments the same muscle in the opposite limb as a control.

2. Deep Heating

Short-wave diathermy was applied to the lower limb, using a standard apparatus of 300 watts maximum output at a frequency of 27·12 megacycles (Stanley Cox "Intertherm") with rigid disk electrodes of 7 inches diameter (Bauwens type) at 1-inch spacing, tuned to maximum skin temperature tolerance. The period of heating was 20 minutes and was preceded by a preliminary observation period. Skin temperature was recorded before and after heating, the thermocouple being removed during heating to avoid burns due to concentration of the electromagnetic field. In separate experiments knee and muscle temperature was measured by means of a needle thermocouple before and after heating.

The sites studied were the skin of the thigh, either under an electrode or midway between the electrodes, the quadriceps muscle, the anterior tibial muscle, the same sites in the opposite leg, and the knee-joint. The scintillation counters were removed from the diathermy field during heating of the knee, as they were on either side of the joint as described and would interfere with the electromagnetic field.

RESULTS

1. Superficial Heating

(a) skin

In the eight subjects studied the clearance rate increased by an average of 50%. This increase started during heating and was greatest after cessation of heating in six subjects; one had no change, and the other had an increase of nearly 200% during heating, falling to a 33% increase on cessation of heating (Table I; Fig. 2). The average skin temperature rise was 6·0° C. to approximately 37° C.

(b) proximal muscle

The quadriceps muscle had an average increase of 19% in the 16 subjects studied. During heating there was a decreased clearance rate in three subjects; two of these had a decrease to 50% (approximately), reverting to the initial value after heating, and the other had a reduction to 14% for nine minutes, which gradually increased to 82% of the initial value for the remainder of the experiment.

TABLE I

EFFECT OF INFRA-RED HEATING ON SKIN CLEARANCE OF RADIOACTIVE SODIUM

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
65	0·051	0·059	0·110
66	0·036	0·050	0·090
67	0·070	0·078	0·085
68	0·067	0·073	0·073
69	0·097	0·097	0·130
70	0·043	0·110	0·057
71	0·059	0·070	0·082
72	0·034	0·055	0·076
Mean	0·060	0·074	0·090
S.D.	0·017	0·018	0·022

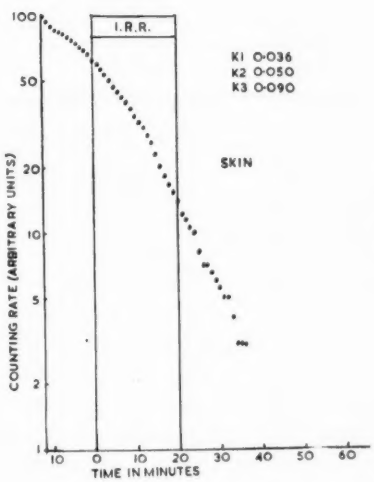

FIG. 2.—Effect of infra-red heating on skin clearance of ^{24}Na (Subject No. 66). A gradual increase of circulation is shown. K1, K2, K3 are clearance constants before, during, and after heating.

Three subjects had an increase greater than 10% during heating, and this was maintained. Ten subjects showed no change. After heating, seven subjects showed an increased clearance of over 10% compared with the initial value, in four of them over 50% (Table II; Figs. 3 and 4). Six subjects showed no change throughout the experiment.

Thus there was an increase in less than half the subjects, and in only four was this greater than 50%.

TABLE II

EFFECT OF INFRA-RED HEATING ON CLEARANCE OF RADIOACTIVE SODIUM FROM QUADRICEPS FEMORIS MUSCLE

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
73	0·045	0·045	0·055
74	0·040	0·040	0·040
75	0·046	0·046	0·049
76	0·039	0·021	0·039
77	0·040	0·017	0·043
78	0·051	0·007	0·042
79	0·024	0·038	0·046
80	0·024	0·049	0·037
81	0·043	0·043	0·043
82	0·039	0·039	0·097
83	0·040	0·054	0·072
84	0·055	0·055	0·070
85	0·064	0·072	0·072
86	0·078	0·078	0·078
87	0·059	0·059	0·059
88	0·061	0·061	0·061
Mean	0·047	0·045	0·056
S.D.	0·014	0·018	0·017

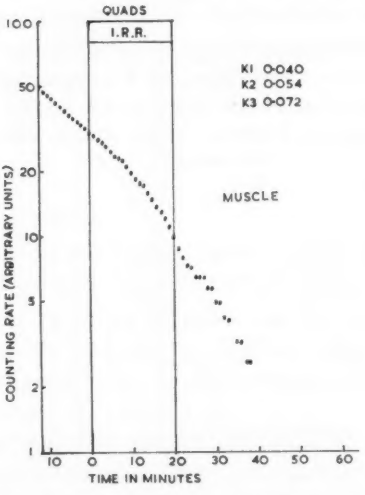

FIG. 3.—Effect of 20 minutes' infra-red heating on clearance of ^{24}Na from thigh muscles (Subject No. 83). A small increase has occurred.

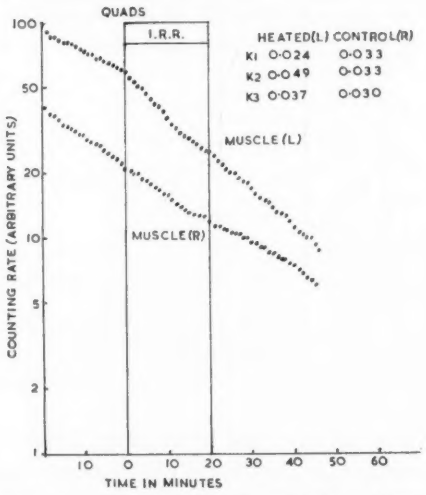

FIG. 4.—Effect of 20 minutes' infra-red heating on clearance of ^{24}Na from quadriceps muscles of heated and opposite leg measured simultaneously (Subject No. 80). There is no change in control limb, but heated limb shows an increased clearance.

The control muscles showed no change during heating, and a small rise (approximately 15%) in six of the nine subjects after heating (Table III). The

TABLE III

EFFECT OF INFRA-RED HEATING ON CLEARANCE OF RADIOACTIVE SODIUM FROM QUADRICEPS FEMORIS MUSCLE OF OPPOSITE LEG

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
73A	0·043	0·043	0·048
74A	0·032	0·034	0·042
75A	0·032	0·032	0·043
76A	0·029	0·029	0·029
77A	0·034	0·034	0·040
78A	0·021	0·021	0·035
79A	0·021	0·027	0·032
80A	0·033	0·033	0·030
81A	0·049	0·049	0·049
Mean	0·033	0·034	0·036
S.D.	0·009	0·008	0·008

average skin temperature rises were 6·5° C. for the heated limb and 0·5° C. for the control limb.

(C) DISTAL MUSCLE

The anterior tibial muscle showed an increase in all five subjects, to approximately 100% in four and 10% in the other. The increase began during heating and was greatest after cessation of heating. The control muscles in the opposite leg all had an increase, the average being 85%, mainly occurring after heating (Tables IV and V; Fig. 5).

This shows the great increase in clearance rate of the distal muscle in response to superficial heating as compared with the proximal muscle, the same variation occurring in the opposite limb muscles.

The changes in the proximal muscles may have been the result of a general rise in body temperature, but the change in the distal control leg must be part of a reflex mechanism.

The average skin-temperature rise in the anterior tibial area was 10° C. to 39° C. for the heated limb and 1° C. for the control.

(D) KNEE-JOINT

This shows an average increase of 37%, starting during heating and rising a little after heating. Only one of the six subjects studied showed no change (Table VI; Fig. 6).

The average skin-temperature rise in the 35 subjects studied was 6·8° C. to approximately 36° C.

TABLE IV

EFFECT OF INFRA-RED HEATING ON CLEARANCE OF RADIOACTIVE SODIUM FROM ANTERIOR TIBIAL MUSCLE

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
89	0·044	0·046	0·049
90	0·042	0·042	0·076
91	0·035	0·050	0·076
92	0·025	0·039	0·055
93	0·055	0·055	0·097
Mean	0·040	0·046	0·071
S.D.	0·010	0·006	0·017

TABLE V

EFFECT OF INFRA-RED HEATING ON CLEARANCE OF RADIOACTIVE SODIUM FROM ANTERIOR TIBIAL MUSCLE OF OPPOSITE LEG

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
89A	0·037	0·040	0·045
90A	0·032	0·032	0·046
91A	0·029	0·043	0·066
92A	0·020	0·039	0·059
93A	0·055	0·055	0·105
Mean	0·035	0·042	0·064
S.D.	0·012	0·008	0·022

2. DEEP HEATING

(A) SKIN

The clearance rate increased by approximately 150% under an electrode and 70% midway between the electrodes (Tables VII and VIII; Figs. 7 and 8). The increase occurred mainly after cessation of heating. The skin clearance rate in the control leg increased by 9% (Table IX).

The average skin-temperature rise was 5·3° C. under the electrode and 1·3° C. between the electrodes. The average skin-temperature rise in the control limb was 1·0° C.

TABLE VI

EFFECT OF INFRA-RED HEATING ON CLEARANCE OF RADIOACTIVE SODIUM FROM KNEE-JOINT

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
94	0·040	0·044	0·049
95	0·019	0·033	0·035
96	0·030	0·030	0·030
97	0·025	0·033	0·035
98	0·027	0·029	0·037
99	0·021	0·037	0·037
Mean	0·027	0·034	0·037
S.D.	0·007	0·005	0·006

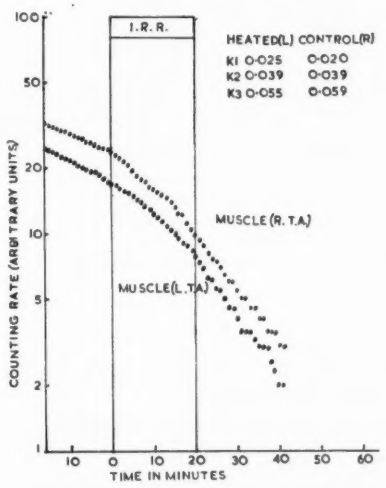

FIG. 5.—Effect of infra-red heating on clearance of ^{24}Na from anterior tibial muscles (Subject No. 92). Both limbs show a large increase.

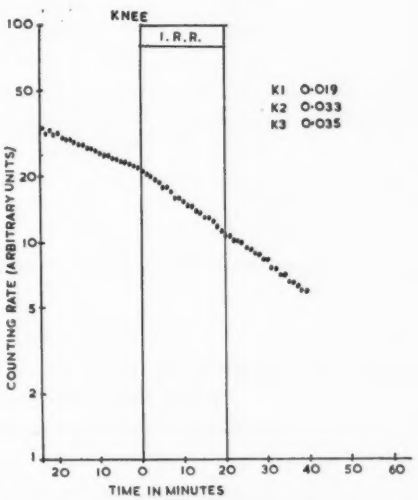

FIG. 6.—To show small increase of clearance of ^{24}Na from normal knee-joint during infra-red heating (Subject No. 95).

(B) PROXIMAL MUSCLE

The quadriceps muscle clearance rate increased by an average of 36%, with 19 of the 25 subjects showing a change. Of these, one had a decrease to 61%, three had a "cut-off" of 4–8 minutes at the onset of heating followed by a return to the initial clearance rate; six had a "cut-off" for 4–5 minutes at the onset of heating, followed by an increased clearance rate compared with the initial figure;

TABLE VII

EFFECT OF SHORT-WAVE DIATHERMY ON SKIN CLEARANCE OF RADIOACTIVE SODIUM UNDER ELECTRODES

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
100	0·027	0·032	0·055
101	0·045	0·088	0·108
102	0·050	0·064	0·197
103	0·038	0·059	0·116
104	0·042	0·042	0·155
105	0·031	—	0·072
106	0·041	0·044	0·078
107	0·074	0·074	0·093
108	0·040	—	0·128
109	0·042	0·042	0·078
110	0·064	0·062	0·136
111	0·031	0·031	0·093
112	0·064	0·064	0·156
113	0·023	0·028	0·084
114	0·029	—	0·125
115	0·041	0·041	0·060
Mean	0·043	—	0·108
S.D.	0·014	—	0·038

TABLE VIII

EFFECT OF SHORT-WAVE DIATHERMY ON CLEARANCE OF RADIOACTIVE SODIUM FROM SKIN MIDWAY BETWEEN ELECTRODES

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
116	0·040	0·056	0·102
117	0·047	0·041	0·041
118	0·034	0·027	0·034
119	0·058	0·058	0·089
120	0·043	0·043	0·111
Mean	0·044	0·045	0·075
S.D.	0·008	0·011	0·032

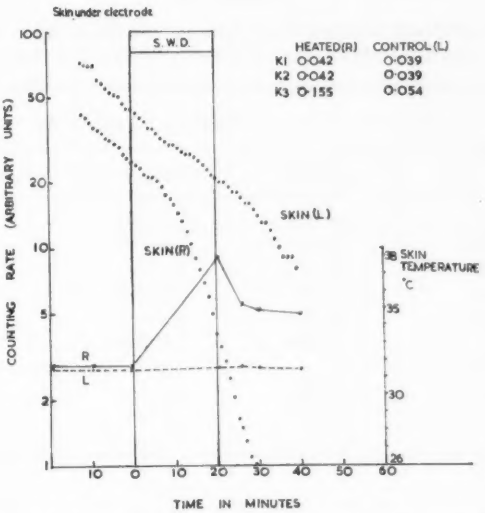

FIG. 7.—To show great increase of clearance in skin under an electrode during and after short-wave diathermy (Subject No. 104). Opposite leg skin clearance shows a delayed response. Skin temperature rise was 6° C. under electrode.

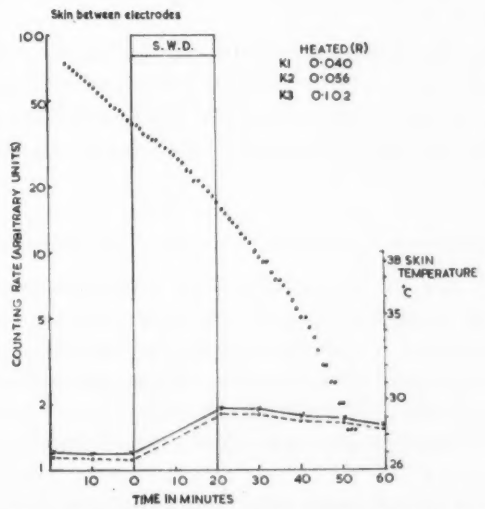

FIG. 8.—The skin midway between electrodes shows a slow increase in clearance rate during and after short-wave diathermy (Subject No. 116). Skin temperature rose 2° C. at this site.

TABLE IX

EFFECT OF SHORT-WAVE DIATHERMY ON SKIN CLEARANCE OF RADIOACTIVE SODIUM FROM OPPOSITE LEG

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
103A	0·052	0·042	0·042
104A	0·039	0·039	0·054
105A	0·025	—	0·032
106A	0·059	0·064	0·078
107A	0·109	—	0·102
108A	0·058	0·058	0·064
Mean	0·057	—	0·062
S.D.	0·026	—	0·023

and the nine remaining subjects had a gradual increase after the onset of heating. Six subjects showed no change (Table X).

The control group showed an average increase of 2% (Table XI; Figs. 9, 10, and 11).

The average skin-temperature rise of the heated limb was 5·2° C., and of the control limb 1·9° C.

This illustrates the varied response of proximal-muscle clearance to heating by a high-frequency current, some subjects having an increase of about 100%, preceded in a few by a decrease, and others had only a small increase, also preceded by a decrease in a few. Four subjects had an over-all decrease and six had no alteration.

(C) DISTAL MUSCLE

The clearance rate of the anterior tibial muscle increased in all subjects studied, the average increase being 60%. During heating the results were uneven, but two subjects showed a decrease and one an increase. The control group showed an increase in four subjects and no change in one subject; the average increase was 57% (Tables XII and XIII; Fig. 12).

The average skin-temperature rise of the heated limb was 5·4° C., and of the control limb 1·1° C.

During heating the clearance rate was uneven in some subjects, and a clearance constant was not calculated.

The average muscle-temperature rise was 4·0° C. (measured in separate experiments).

TABLE X

EFFECT OF SHORT-WAVE DIATHERMY ON CLEARANCE OF RADIOACTIVE SODIUM FROM QUADRICEPS FEMORIS MUSCLE

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
121	0·025	Short "cut-off"	0·047
122	0·050	,,	0·110
123	0·032	,,	0·041
124	0·032	,,	0·085
125	0·029	,,	0·037
126	0·067	,,	0·090
127	0·029	,,	0·031
128	0·036	,,	0·038
129	0·053	,,	0·055
130	0·039	0·058	0·058
131	0·026	0·029	0·055
132	0·032	—	0·056
133	0·025	—	0·046
134	0·054	0·064	0·079
135	0·039	—	0·051
136	0·035	0·054	0·077
137	0·043	0·046	0·053
138	0·032	0·047	0·061
139	0·041	0·041	0·041
140	0·038	0·038	0·038
141	0·081	0·076	0·081
142	0·049	0·049	0·049
143	0·044	0·044	0·044
144	0·061	0·061	0·061
145	0·044	0·021	0·027
Mean	0·042	—	0·057
S.D.	0·013	—	0·020

(D) KNEE-JOINT

All subjects showed increases in clearance after heating ranging from 40% to 160%, the average increase being 82% (Table XIV; Fig. 13). The increase was maintained during the period of observation, which lasted 10–20 minutes after cessation of heating.

The average intra-articular temperature rise was 4·5° C.

This demonstrates the different response of proximal and distal muscles to short-wave diathermy in both the heated and control leg, and the great increase of skin and joint clearance.

TABLE XI

EFFECT OF SHORT-WAVE DIATHERMY ON CLEARANCE OF RADIOACTIVE SODIUM FROM QUADRICEPS FEMORIS MUSCLE OF OPPOSITE LEG

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
121A	0·029	—	0·038
127A	0·030	0·030	0·030
128A	0·044	0·044	0·044
129A	0·052	0·052	0·052
131A	0·031	0·031	0·031
132A	0·048	0·040	0·038
133A	0·027	—	0·050
134A	0·057	—	0·053
135A	0·026	0·027	0·030
136A	0·036	0·035	0·050
139A	0·041	0·041	0·041
140A	0·041	—	0·030
141A	0·068	0·068	0·068
Mean	0·041	—	0·042
S.D.	0·013	—	0·09

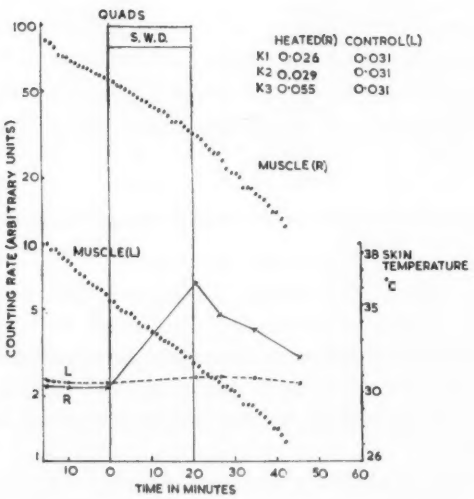

FIG. 9.—Short-wave diathermy (Subject No. 131). Showing gradual increase of clearance of ^{24}Na from quadriceps muscle of heated limb 15 minutes after start of heating. Increase is confined to heated limb.

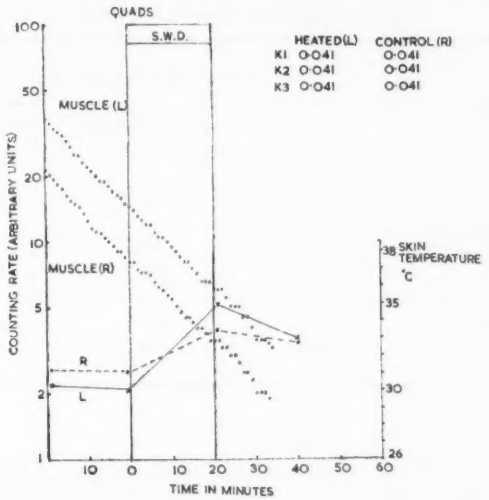

FIG. 10.—To show that no change takes place in clearance of ^{24}Na from quadriceps muscle of either limb during or after short-wave diathermy (Subject No. 139).

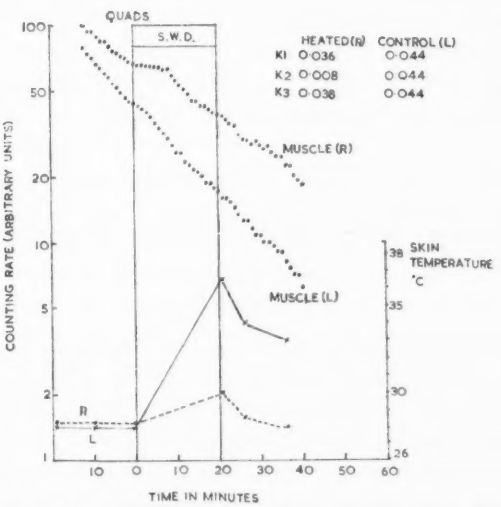

FIG. 11.—In approximately one-third of the experiments a great reduction in the clearance of ^{24}Na occurred soon after the application of short-wave diathermy. No change in opposite limb. (Subject No. 128.)

TABLE XII

EFFECT OF SHORT-WAVE DIATHERMY ON CLEARANCE OF RADIOACTIVE SODIUM FROM ANTERIOR TIBIAL MUSCLE

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
146	0·059	—	0·076
147	0·079	0·063	0·097
148	0·018	—	0·039
149	0·068	0·052	0·095
150	0·039	0·072	0·110
Mean	0·053	—	0·083
S.D.	0·022	—	0·025

TABLE XIII

EFFECT OF SHORT-WAVE DIATHERMY ON CLEARANCE OF RADIOACTIVE SODIUM FROM ANTERIOR TIBIAL MUSCLE OF OPPOSITE LEG

Subject	Clearance Constant (K)		
	Initial	During Heating	After Heating
146A	0·040	—	0·071
147A	0·031	0·025	0·034
148A	0·044	—	0·056
149A	0·066	—	0·092
150A	0·039	0·065	0·093
Mean	0·044	—	0·069
S.D.	0·012	—	0·022

DISCUSSION

It has been shown by plethysmography that superficial heating increases the total limb blood flow (Barcroft and Edholm, 1943, 1946) and that raising the body temperature, such as by immersion in a warm bath, increases the total forearm blood flow. The increase was thought to be in both the skin and muscle and has been the subject of many papers. The skin flow was reduced by adrenaline ionization in some experiments, and the remaining blood-flow changes were stated to be in the muscle (Barcroft, Bonnar, and Edholm, 1947). Recently Edholm has shown that the method of skin adrenaline ionization used previously was inadequate, and repeated the experiments, showing that if skin blood flow is completely arrested by adrenaline ionization, then no blood-flow change

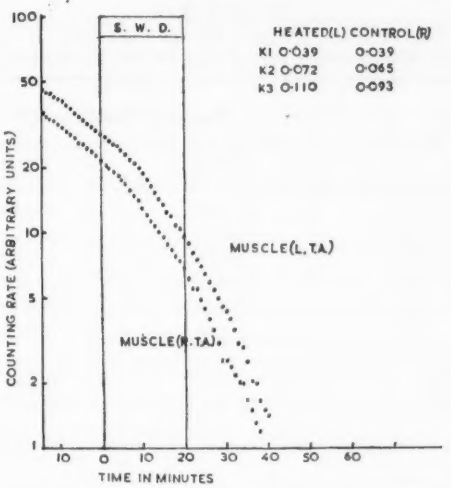

FIG. 12.—Showing great increase in clearance of ^{24}Na produced by short-wave diathermy applied to anterior tibial area (Subject No. 150). Both limbs show similar increases.

occurs in the muscle in the forearm, as measured by plethysmography, when the body temperature is raised by heating (Edholm *et al.*, 1956). These findings bear a close relation to those of Harris *et al.* (1952), who used the clearance of radioactive sodium to study the effects of trunk heating on the upper-limb blood flow, and showed that there was a decrease in the clearance rate from muscle during trunk heating followed by either an increase or a return to the initial value, and also that of Roddie *et al.* (1956) using oxygen-saturation alterations as a measure of blood flow.

The experiments described here show that skin blood flow varies directly with temperature changes, and that both superficial and deep heating (which also heats the skin) produce large increases (approximately 50% and 100% respectively) which, if measured by plethysmography, would be shown as part of the total blood flow and could produce erroneous results in studies of muscle blood flow. Muscle clearance rates show very different results in the proximal and distal groups in the lower limb, the former having far less change than the latter in response to superficial or deep heating. In addition, the distal muscle of the opposite control limb showed greater changes than the proximal muscle, which suggests a reflex mechanism in the distal muscle, as the rise in blood flow is much greater than the change in temperature.

The greatest increase in clearance from muscle after heating was in response to superficial heating by infra-red rays and was in the anterior tibial muscles, which had an average increase of 78% in the heated limb and 85% in the control limb.

TABLE XIV

EFFECT ON CLEARANCE CONSTANT OF HEATING KNEE-JOINT FOR TWENTY MINUTES WITH SHORT-WAVE DIATHERMY

Subject	Clearance Constant (K)	
	Initial	After Diathermy
151	0·044	0·092
152	0·033	0·052
153	0·028	0·050
154	0·079	0·109
155	0·046	0·120
156	0·034	0·055
Mean	0·044	0·080
S.D.	0·019	0·043

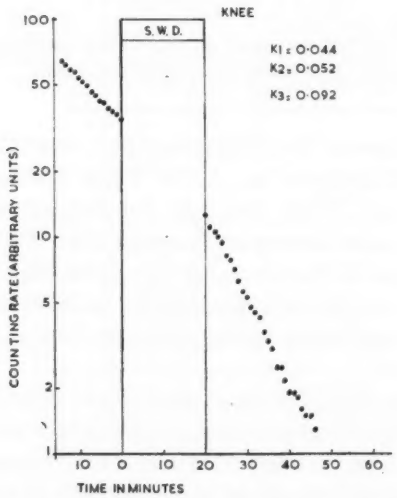

FIG. 13.—Short-wave diathermy produced an increased rate of clearance of ^{24}Na from normal knee-joint lasting more than 30 minutes (Subject No. 151).

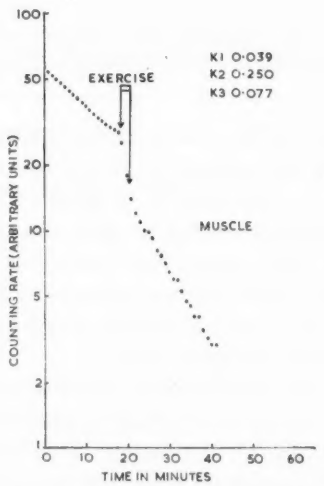

FIG. 14.—Showing comparatively great increase in rate of clearance of ^{24}Na from muscle during and after two minutes' gentle exercise (Subject No. 34).

The changes due to heating, however, are small compared with the effect of a few minutes' gentle exercise, which produces an increase in the clearance rate of several hundred per cent both during and after exercise (Fig. 14) (Gaskell, 1877; Barcroft and Dornhurst, 1949a, b). Walder (1953) found an increase during exercise, but only for a short period after the cessation of exercise. He found an increase of greater duration after exercise when studied by plethysmography, and concluded that each method measured a different blood-flow factor. Walder's

subjects carried out severe exercise and the gastrocnemius muscle was studied, compared with the gentle exercise of the quadriceps muscle studied in a personal series.

The effects of high-frequency currents (short-wave diathermy) and non-ionizing radiations (infra-red rays) on the blood flow have been studied by a few investigators, but the majority used the plethysmograph and measured total blood flow in the limb.

Abrahamson *et al.* (1957) tried to measure muscle blood flow with plethysmographic studies of the forearm during diathermy, by increasing the water-bath temperature to 45° C. They found an increase in blood flow during heating, and state that it must be in the muscle, as the skin blood flow was already at a maximum due to the surrounding water at 45° C. The diathermy electrodes were applied to the hand and shoulder in order to heat the forearm, which was surrounded by a water-filled metallic plethysmograph, and it is doubtful whether the muscle temperature was altered by the diathermy, as the plethysmograph would act as a shunt and distort the electromagnetic field.

Wakim *et al.* (1948) carried out plethysmographic studies during short-wave diathermy applied to the upper and lower limbs and found an average increase of 50%, with a few subjects showing a decrease of 10–15%, but these authors measured total blood flow.

Wise (1948) used the plethysmograph to study total forearm blood-flow changes and reported a definite rise during diathermy, but Millard (1955), using the rate of clearance of radioactive sodium, observed inconstant changes during short-wave diathermy to the thigh muscles.

Other workers have studied the effects of temperature changes on the blood flow of anaesthetized animals using direct measurements. The majority state that, unless a critical temperature of approximately 43° C. is reached, then no significant increase in blood flow occurs in muscle, but that joint blood flow gradually increases (Wakim *et al.*, 1948; Kemp *et al.*, 1948; Richardson, 1954; Richardson *et al.*, 1950; Cobbold and Lewis, 1956a, b). This critical temperature of 43° C. is several degrees higher than can be obtained in human beings by therapeutic measures (Richardson *et al.*, 1950; Barcroft *et al.*, 1952).

The effect of infra-red radiation is probably similar to that of any other form of superficial heating, as the penetration is less than 10 mm. The skin blood-flow changes were described by Lewis (1927) and the muscle blood-flow changes by Barcroft and Edholm (1943, 1946); Stoner (1958), Sweeney and Stoner (1951) and many others, all agreeing that an increase occurs. The method used to study blood flow was plethysmography, and, in view of the recent work of Edholm *et al.* (1956) showing that this method may produce fallacious results and also that the increase is confined to the skin if reflex heating effects are studied, it may be that superficial heating does not alter muscle blood flow as much as expected.

A reduction in blood flow of the thigh of anaesthetized dogs is reported by

Franke *et al.* (1950), who used the radioactive sodium clearance technique to study the effects of local heating or cooling.

The knee-joint showed similar changes to muscle, but with the greatest increase due to deep heating. Previous work by Horvath and Hollander (1949), who studied joint-temperature changes during heating or cooling by the application of moist towelling, suggested that a reciprocal reflex existed between skin and joint blood flow, the latter increasing if the skin is cooled. This was not found by Whyte and Reader (1952), who heated a knee-joint with infra-red rays and found a slight decrease of joint temperature followed by a gradual increase to 36° C. The present experiments show that a direct reflex occurs, skin and joint blood flow gradually increasing, and confirm the work of Cobbold and Lewis (1956a), who found similar results using direct measurements.

Bonney *et al.* (1952) found that reflex heating increased the knee-joint blood flow by 15–30%, but used a plethysmograph and tried to differentiate between superficial and deep blood flow by adrenaline ionization. The ionization current may not have been sufficient to influence the skin flow, and as the plethysmograph enclosed some muscle the blood-flow increase may have been partially in the skin and muscle.

The results of the investigations described in this paper show that superficial and deep heating alter the skin blood flow as expected (Lewis, 1927), but that the change in muscle is small, being much less in the proximal muscle than the distal muscle. Several minutes' gentle exercise produces much greater changes in blood flow in muscle than any form of heating. The joint changes are similar to those of muscle, but with a greater response to deep heating.

Compared with other methods of measuring blood flow, the changes in muscle are smaller than expected. This supports recent findings that the skin blood-flow changes may cause erroneous results by being measured as part of the deeper blood flow, but the blood-flow increases in the unheated limb support the earlier plethysmographic studies of reflex heating.

It must be remembered that the clearance of ^{24}Na measures capillary blood flow within certain limits, and any variance in results between this and other methods which measure blood flow may be due to the presence of unknown factors, such as an arterio-venous shunt mechanism, which would increase the total blood flow and not affect the clearance of ^{24}Na, as suggested by Barcroft and Swan (1953), or some other mechanism of alternative capillary blood flow.

The different response of the proximal and distal muscle blood flow to heating suggests that there may be a different control mechanism. This control appears to be a nervous mechanism in the distal muscles involving a spinal reflex, because the distal muscles of the opposite limb showed similar blood-flow alterations with only a small skin-temperature rise. The changes in proximal-muscle blood flow were small, and the changes in the opposite limb could be the result of a general body-temperature rise.

CONCLUSIONS AND SUMMARY

The purpose of these experiments was to try to determine the effects of superficial and deep heating on the blood flow of the lower limb. The results show clearly that the blood flow in the skin is increased in the heated limb, but the blood flow of the underlying muscle varies with the site, the proximal muscle showing very little change and the distal muscle showing an increase. There are minor differences in the muscle blood-flow changes in response to superficial or deep heating. Deep heating produced greater changes in the proximal muscle than superficial heating. Superficial heating produced greater changes in the distal muscle than deep heating. However, both types of heating produced the greatest changes in blood flow in the distal muscle of the heated limb, and to a less degree in the control limb. The knee-joint blood flow was greatest with deep heating.

The experiments show that blood-flow changes may be small or up to 100% with either type of heating, but exercise increases the muscle blood flow much more (Fig. 14). It is known that heat relieves pain, and it is used extensively in therapeutics for this purpose, but, as the blood-flow changes in the deeper tissues are small, there may be other factors connected with the physiology of pain which are altered by heat, producing relief; for example, heat may produce "counter-irritation" or alteration of the cold pain mechanism by raising the tissue temperature, and further experiments to determine this are necessary (Kellgren *et al.*, 1948).

As the therapeutic use of superficial heating produces changes similar to deep heating in conditions in which the aim is to increase blood flow in the muscular tissue, infra-red radiation should produce equally good results. This is important from the economical aspect, as an infra-red lamp is much cheaper than a short-wave diathermy machine.

Patients with lesions of the knee-joint should obtain greater benefit from deep heating if an increase in joint temperature and blood flow is the aim, although other factors than blood-flow changes may influence the sensation of pain, as previously suggested. If the aim of heat therapy is to cause an increase in blood flow in skin or muscle there is very little to choose between either type of heating, but, as it has been shown that short-wave diathermy sometimes reduces the muscle blood flow temporarily, superficial heating may be safer. Infra-red radiation produces blood-flow increases in the distal muscles of the unheated limb, and therefore might be useful to improve blood flow in certain peripheral vascular disorders without heating the affected limb.

The experiments show that the effects of high-frequency currents and non-ionizing radiations on the circulation of the lower limb are similar, producing small increases in the proximal-muscle, greater increases in the distal-muscle, and, in the control limb, increases in the distal-muscle blood flow. High-frequency currents cause an increase in blood flow in the knee-joint. Skin blood flow is increased by both types of heating.

ACKNOWLEDGMENTS

I wish to acknowledge the generous help of Dr. R. Harris of the Manchester Royal Infirmary, Dr. Gilbert of the Christie Hospital, Manchester, and Drs. F. S. Cooksey and J. Fowler of King's College Hospital, London.

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The ratemeters used were Type N.522 Ekco Electronics Equipment, in conjunction with scintillation counters Type N.509 Ekco Electronics Equipment.

This work is part of the subject-matter included in a thesis for which the M.D. was awarded by London University.

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ORIGINAL PAPER

LAMINECTOMY FOR CERVICAL SPONDYLOSIS*

INDICATIONS AND RESULTS OF OPERATION

By F. L. DAVIES

From Hurstwood Park Hospital, Haywards Heath, and Royal Sussex County Hospital, Brighton

THE precise indications for surgery in the treatment of cervical spondylosis are not fully established. International opinion varies from strict conservatism to radical operation, and in spite of much work and study in the last decade the published results of operation—especially in cases with myelopathy—have been disappointing.

As Campbell and Phillips (1960) have recently stressed, confusion in assessing results often arises from failure to distinguish the main types of lesion found in association with cervical spondylosis. These authors show that most cases fall into the following groups:

1. Cervical spondylosis with myelopathy.
2. Cervical spondylosis with brachial neuritis.
3. Prolapsed cervical nucleus pulposus.
4. Cervical spondylosis with myelopathy due partly or wholly to other aetiology.

For the purpose of this paper I will not refer to Group 4 except to emphasize the importance of making a correct diagnosis and giving conservative methods of treatment adequate trial before resorting to surgery.

INDICATIONS FOR OPERATION IN CERVICAL SPONDYLOSIS WITH MYELOPATHY

Most workers in this field are agreed that in the majority of cases conservative treatment should be given an adequate trial (Brain, Northfield, and Wilkinson, 1952)—in the absence of deterioration—at least six months. Operation is indicated if there is progressive deterioration despite treatment, as, if this deterioration is rapid and crippling, surgery may be the only method of preventing or delaying progression of the disease.

Operative Procedure

The usual operation performed is decompression of the theca and spinal cord by a formal laminectomy—one above and below the protrusion—and removal of the ligamentum flavum. The number of laminae removed will depend on the extent of the lesion. In most cases this procedure is sufficient to relieve or arrest the symptoms.

* Paper read at the Provincial Meeting of the British Association of Physical Medicine, Brighton, October, 1960.

An extension of this operation consists in opening the dura and dividing the dentate ligaments on each side within the limits of the exposure. This procedure has been followed by neurosurgeons for many years, and Northfield (1955) has shown that satisfactory results are possible. Recent opinion is, however, divided on the advisability of opening the dura with the possibility of introducing infection, and it is doubtful if the small amount of extra mobility obtained justifies the risk to the spinal cord with a potentially precarious blood supply.

Results of Operation

The results of this type of operation are difficult to assess, and, apart from Northfield (1955) and Campbell and Phillips (1960), there have been no prolonged follow-ups of surgical cases. There has also been the difficulty of deciding criteria of partial improvement, especially as there is a tendency for spontaneous arrest, and rest in bed before operation often results in improvement.

The largest personal series of laminectomy with section of the dentate ligament is that of Northfield (1955), whose results in 39 cases were: considerably improved, 13; slight improvement, 9; stationary, 8; slowly worsened, 8; death, 1.

These results, together with others for comparison, are shown in Table I.

Excision of Osteophytic Spurs

The more radical removal of bony spurs and ridges has been recommended by Allen (1952), and in his hands there have been no further complications. Most surgeons in Great Britain feel there is a danger in working anterior to an already damaged spinal cord with a poor blood supply. The operation consists in a laminectomy with exposure of the protrusion; the nerve root or cord is retracted, the posterior longitudinal ligament divided, and the osteophyte chiselled away. The long-term results of this procedure have not yet been published, and the author has carried out this step in only two cases; in one case the immediate result was poor and recovery was slow, and the other case seemed to benefit as relief of pain was relatively rapid.

Grafting Operations

If there is subluxation of a cervical vertebra, or if there is instability or deformity following cervical laminectomy, fixation can be obtained by a posterior bone-graft with or without wiring of the adjacent spinous processes. This method is not uniformly successful, as the cervical spine is difficult to immobilize, especially if many laminae have been removed. Attempts have been made to obtain fusion by the anterior route.

The great vessels of the neck are retracted and a groove is cut in the anterior aspect of the vertebral bodies and disk; into this bed a bone-graft is placed.

Another method (Rand, 1960) involves the removal of a circular cylinder of bone from the adjacent bodies and disk; the protrusion or osteophyte is removed

TABLE I

RESULTS OF CERVICAL LAMINECTOMY

Author	Disease	Improvement			Unchanged or Worse
		Much	Moderate	Slight	
Northfield (1955)	Cervical spondylosis with myelopathy	13		9	16
Arnold (1955)	„ „	2	2	1	3
Walsh and Mackenzie (1956)	„ „		13	4	11
Campbell and Phillips (1960)	„ „	3		4	3
Davies (1960)	„ „	5			1
Campbell and Phillips (1960)	Prolapsed nucleus pulposus	5			1 died
Frykholm (1951)	„ „	15	5	5	
Davies (1960)	„ „	4	1		
Campbell and Phillips (1960)	Cervical spondylosis with brachial neuritis	9		1	1 recurrent

from in front through this space (i.e. anterior to the cord), and the cylinder is then replaced. These methods are regarded as experimental at present and critical long-term reports have not been published.

CERVICAL SPONDYLOSIS WITH BRACHIAL NEURITIS

INDICATIONS FOR OPERATION

These are: (1) failure of at least twelve weeks' conservative treatment; (2) if the symptoms are exceptionally severe; (3) recurrent attacks (three or four within 12 months); (4) severe motor weakness and paralysis.

TECHNIQUE

This will depend on the site of the protrusion. A dorso-lateral protrusion will require a hemilaminectomy to remove compression on the nerve. If the protrusion is intraforaminal, then a hemifacetectomy is necessary. In each case the nerve is fully exposed and decompressed from behind, and this avoids the need to retract the nerve to remove an osteophyte situated anteriorly (see Diagram). The approach is the same for both procedures—that for a hemilaminectomy—with separation of the muscles from the spines and laminae; the ligamentum flavum is removed, the protrusion identified, and the appropriate area of bone removed. A small (1·5-cm.) burr is used to expose the nerve by hemifacetectomy. If the protrusion is soft and easily accessible without undue retraction of the nerve root, then it is removed at the same time.

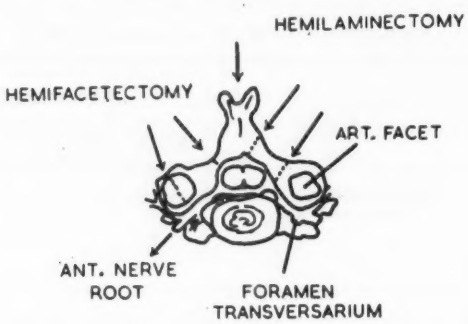

Diagram showing operation according to site of protrusion in cervical spondylosis with brachial neuritis.

Should there be evidence of root-sleeve fibrosis, Frykholm (1951) advises an incision in the long axis of the nerve-root pouch laterally to include the region of the root ostium.

Results

Since few series have been analysed the results are difficult to assess. Frykholm (1951) reported 25 patients with annular protrusion followed for not less than two years. Of these, 15 showed considerable improvement, 5 moderate improvement, and 5 were unchanged or worse. In general, it would seem that there is a 60% to 65% chance of a good result in spondylosis (Logue, 1957). The results obtained in soft nuclear protrusion are better. (See Table I.)

PROLAPSED CERVICAL NUCLEUS PULPOSUS

The operative technique for this condition is well established and is similar to that described for hemilaminectomy. The results are good (Campbell and Phillips, 1960; O'Connell, 1955, 1956) (see Table I).

If the prolapse is situated laterally, removal is relatively simple, but a central protrusion in the cervical region can be difficult in view of the retraction of the cord necessary to gain access; a transdural approach is sometimes safer.

CONCLUSION

For the purpose of this paper I have included cases admitted to Hurstwood Park Hospital in the past three years. The small number of all cases reflects the current conservative trend (Table II). At a recent international meeting of neurosurgeons at Edinburgh the treatment of cervical spondylosis was discussed at some length. There was a significant emphasis on the value of conservative treatment of cervical spondylosis with myelopathy or with brachial neuritis. It was generally felt that surgery is indicated in those cases with rapidly progressive myelopathy, in

TABLE II

TREATMENT OF CASES OF CERVICAL SPONDYLOSIS ADMITTED TO HURSTWOOD PARK HOSPITAL DURING LAST THREE YEARS

Disease	Treatment		Total No. of Cases
	Conservative (No. of Cases)	Operative (No. of Cases)	
Cervical spondylosis	34	6	40
Prolapsed cervical intervertebral disk ..	0	5	5
Cervical spondylosis with other diseases ..	1 disseminated sclerosis 1 syringomyelia	0	2
Total No. of Cases			47

intractable brachial neuritis, and in cases of spinal-cord compression due to prolapsed intervertebral disk.

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ORIGINAL PAPER

CARPAL TUNNEL SYNDROME: TREATMENT BY SPLINTING*

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HEATHFIELD (1957) reported the results of splinting of the wrist in 51 cases of acroparaesthesiae due to compression of the median nerve in the carpal tunnel. He advised a splint in the neutral position. The treatment was successful in 48, gave partial relief in one, and failed in two cases. Of the 48 successful cases, 6 subsequently relapsed and were referred for operation, 5 were referred for operation when free from symptoms, and 3 patients, though not quite symptom-free, declined operation.

This description of a successful conservative treatment for the carpal tunnel syndrome was very welcome, and the method obviously called for a trial. I have since made splinting of the wrist on the more severely affected side the first treatment in all cases of carpal tunnel syndrome. A total of 47 patients—3 men and 44 women—have been observed. The age range was 35 to 55 years, except for three patients who were under 35 and nine who were over 55 years. Of the 47 patients, 24 had had their symptoms for less than a year, 11 for 1 to 5 years, and 12 for over 5 years. Patients whose symptoms had lasted for many years gave a history of exacerbations and remissions.

The diagnosis was made on the typical history of burning pain and tingling in the hands at night, disturbing the patients' sleep. Some patients obtained relief by shaking the hands or hanging them down outside the bedclothes, but others had to get up and pace the room before they could get any relief. Most patients had numbness and stiffness in the hands on waking in the morning, but this soon passed off. Nearly half the patients also had symptoms during the day, such as tingling, especially on using the hand, or weakness and clumsiness of the hand, particularly noticeable when knitting or sewing. Twenty patients stated that the outer fingers were affected but not the little finger, and 27 insisted that all fingers were affected. In 19 cases the burning pain radiated upwards into the arm, but rarely above the elbow. A few had wasting of the thenar eminence or slight sensory loss.

The splint used was of plaster-of-Paris applied on the ventral aspect of the forearm and extending to the fingertips. The wrist was in the neutral position as advised by Heathfield, and the thumb in a position of ease, namely slight adduction. Brain *et al.* (1947) showed that extension of the wrist raised the pressure

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in the carpal tunnel; therefore splinting of the wrist in extension would tend to aggravate the symptoms. Heathfield found that such aggravation of symptoms did sometimes occur with a splint in extension, and that relief was obtained when a splint in the neutral position was substituted.

A small group of patients were first given placebo tablets and later treated with a splint and the results compared. The patients were told to take one placebo tablet three times a day and to report back in one week. They were then supplied with a plaster splint, which they wore at night for a further week. After each week's treatment they were asked to say whether they felt better, worse, or about the same. It was considered that a response to placebo tablets should be apparent after one week. Heathfield reported that in most successful cases splinting was effective immediately, though in a few cases improvement occurred only after a week or more. It seemed reasonable, therefore, to assess the results of splinting after one week.

The results in 19 cases treated with placebo tablets and then by splinting were: after placebo tablets—improved 8, no change 11; after splinting—improved 12, no change 7.

If the degree of improvement of the 8 patients who were better after the placebo is considered it is found that 6 had slight or moderate improvement and 2 marked improvement. By marked improvement is meant that the patient now slept well, without waking during the night. Slight or moderate improvement implies that symptoms were less severe, but the patient still woke at night or on some nights. By contrast, of the 12 patients benefited by splinting, 4 had moderate and 8 marked improvement. The patients were also asked whether the splint was more or less helpful than the tablets. Of the 8 who improved with the placebo, 6 thought the splint better, 2 noticed no difference, and none thought the splint inferior to the tablets. My impression was that the splint was definitely helpful in some cases, and I think these results with placebo tablets lend support to this view.

The results for 47 patients treated by splinting were: improved, 28; no change, 16; worse, 3. Of the 28 successful cases, 22 had marked relief and 6 moderate relief after one week. The splint was applied to the more severely affected hand in bilateral cases. Relief of symptoms in this hand was usually enough to ensure sleep, but in five cases splints were required for both wrists. It was not always necessary for the patients to wear both splints on the same night, as usually only one hand was particularly troublesome and splinting on this side was sufficient.

The records show that some of the 28 patients who improved with the splints subsequently had a natural remission; others continued to manage well with the splint, but some received hydrocortisone injections into the carpal tunnel or were referred for operation. The injection was undertaken for those who obtained only moderate relief from splinting, or in the hope that it would enable

those with marked benefit to do without the splint. The figures are as follows: remission, 8; managing with splint, 12; given hydrocortisone injection, 8; referred for operation, 4. The fate of the 19 patients who did not improve with splinting was: remission, 4; symptoms insufficient for further action, 2; given hydrocortisone injection, 11; referred for operation, 8. The patients were under observation for periods ranging from two months to over one year.

Nineteen patients received injections of hydrocortisone into the carpal tunnel. The needle was inserted in front of the wrist at the junction of the medial edge of the palmaris longus tendon and the proximal border of the transverse carpal ligament. Hydrocortisone acetate, 25 mg., was injected; no procaine was used. The injection itself did not upset the patients, nor did any of them have much trouble in the succeeding 24 hours. Thirteen patients improved after the injection and 6 had no benefit. Of the 13 who improved, 9 had marked relief and 4 moderate relief in accordance with the grading of improvement given for results of splinting. Unfortunately symptoms started to return in one week or less in 6 cases, but these patients found that their symptoms were less severe for several weeks after an injection. Three patients started to relapse after from two to six weeks. Four patients maintained their improvement while under observation, the period of observation extending up to eight months.

Operation was recommended in 12 cases. This has been carried out in 6 cases, while 4 are awaiting operation and 2 have defaulted. The result of operation was satisfactory in 5 patients but unsatisfactory in one. The operation was performed on one side in 4 cases and on both sides in 2.

DISCUSSION

Heathfield (1957) considered that relief of symptoms by splinting in cases of acroparaesthesiae supported the diagnosis of the carpal tunnel syndrome. He had very few unsuccessful cases—only three in a series of 51. It might be said that the larger number of failures in the present series is due to wrong diagnosis. However, I think relief of symptoms from a local injection of hydrocortisone into the carpal tunnel in cases of acroparaesthesiae can be regarded as supporting the diagnosis of carpal tunnel syndrome. Eight patients in the present series who derived no benefit from splinting obtained relief from a hydrocortisone injection and two were completely relieved by operation, so that not all the failures can be attributed to wrong diagnosis.

Foster (1960) reported better results for hydrocortisone injections into the carpal tunnel. In a series of 20 patients only two derived no benefit from the injections, and the improvement lasted for several months in the majority. His results are not really comparable with mine, however, as he gave his patients three injections at weekly intervals. Only seven of my patients received a second injection, either because the first one failed or because a severe relapse occurred. Foster also had a very high relapse rate.

Simpson (1956) found that conduction in the median nerve was slowed in the carpal tunnel syndrome, but that the conduction time returned to normal after operation. Goodman and Gilliatt (1961) confirmed this work, and also showed that no change occurred in the prolonged conduction times in cases treated by splinting. These studies of conduction times in the median nerve indicate that operation is the best treatment for the carpal tunnel syndrome. Nevertheless I think that splinting has a part to play in the management of these cases. It may help the patient while she is waiting for operation. When symptoms are relieved by splinting the treatment may be continued in the hope that a natural remission will occur; and many patients prefer a simple treatment such as this to operation. Hydrocortisone injections are of value where symptoms are severe and have not responded to splinting. I do not favour repeated injections into the carpal tunnel except to relieve severe symptoms while the patient is waiting for operation.

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ORIGINAL PAPER

OPERATIVE PROCEDURES TO IMPROVE CIRCULATORY DEFECTS WHICH INTERFERE WITH LOCOMOTION*

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ARTERIAL disease affecting locomotion is, unfortunately, an all too common problem, but within the last decade there has been a certain redirection of surgical endeavour away from development of the collateral vessels and in favour of a new arterial channel.

The essence of the problem is simply a reduction of blood-flow, and patients fall roughly into two classes: first, and the least severe, those with claudication, usually of the calf, sometimes of the thigh and buttock, and occasionally of the foot; secondly, and the most serious, those with peripheral ischaemia, whose signs and symptoms vary from coldness and numbness of the foot, passing through various colour changes to rest pain and finally gangrene. The predominant disease in both groups is atherosclerosis with secondary thrombosis. To a much less extent trouble arises from emboli, thromboangiitis obliterans, or aneurysms. Space does not permit a full discussion of the last three conditions, and a few generalizations must suffice. Large emboli are obvious, but small ones may cause only passing coldness and numbness, presenting later with claudication just as in thrombosis of the popliteal artery. Buerger's disease amounts to only 2–3% of cases. It affects predominantly the smaller and peripheral blood-vessels, such as the tibial and plantar arteries and the collaterals and the veins. It may affect so many vessels that ischaemia becomes severe. The problem in this disease, then, is peripheral ischaemia and not claudication. Aneurysms of peripheral vessels are relatively rare, but when they do occur they are most common in the vessels of the lower limb. They may go for a long time without causing trouble, but sooner or later thrombosis occurs and occasionally rupture.

Atherosclerosis affects the big arteries. With reference to the leg, the common starting-points are the superficial femoral just above the adductor foramen and the common iliac arteries. The disease also occurs below the knee in the anterior and posterior tibial and peroneal arteries. The latter is the least affected of the three, and may be sufficient by itself to carry blood to the foot. Atherosclerosis is often a widespread disease affecting not only both legs, or diffusely throughout one leg, but also the coronary and cerebral vessels. In a small number of cases, however, it is apparently localized in the form of either a short but complete block or a stenosis or incomplete block.

Careful examination and inspection can tell us a lot, but the full extent of the disease can only be gauged by arteriography.

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DEVELOPING THE COLLATERAL CIRCULATION

In the past the main hope of improvement for ischaemia has lain with the collateral circulation. Methods to encourage it are among the tasks of a physical medicine department. Its development is a slow process and is largely due to hydrostatic factors. In localized disease the collaterals may be adequate to restore the peripheral pulses—claudication is the only feature. In the more widespread disease with longer collaterals the blood reaches the periphery at a reduced pressure without pulsation. If, in addition, it then enters diseased vessels the ischaemia is usually severe.

Lumbar sympathectomy has long been used to encourage the collateral blood-flow, but its use has been much more restricted of late. Following operation the resting peripheral blood-flow may be doubled. Exercise demands a seven- to ten-fold increase. It follows that it is valueless for claudication. This leaves peripheral ischaemia. In this group some patients are too old or decrepit, while others have too advanced ischaemia for anything other than amputation to be considered. The best results are obtained in cases with coldness and numbness of the foot. Patients with rest pain may be given a trial of vasodilatation, reflex heating, and anticoagulants; if alleviation occurs, then a sympathectomy is worth while. If the proximal main vessels are so diseased that the circulation depends upon tenuous collaterals, then no good can be expected from even a very complete sympathectomy. In Buerger's disease the same principle holds good when both main and collateral vessels are involved. The operation has, of course, no specific effect upon the progress of the disease.

ESTABLISHING A NEW ARTERIAL CHANNEL

The alternative to developing the collaterals is the establishment of a new arterial channel delivering pulsating blood at a high pressure to the popliteal artery. This can be done either by removing the block from the centre of the artery or by a by-pass graft. The former, known as disobliteration, is the method of choice for stenoses and short blocks, especially of the iliac vessels. This is the sort of condition which is found in a small proportion of cases with claudication. The operation consists in incising the wall of the artery in the affected part, finding a plane of cleavage in the muscle, and separating the inner part as a tube. This contains the organized clot, intima, calcified plaques, and part of the muscle wall. The remains of the arterial wall is reconstituted with a continuous stitch. The great advantage of the operation is that no tube of foreign material is introduced into the body. Given a smooth lining and a fast flow of blood, the recurrent clotting rate is relatively low; in addition, the mouths of blocked collaterals may be opened up.

It follows from this that in the treatment of claudication by this method the most successful cases are those with a stenosis or short block in an otherwise healthy arterial tree. Longer blocks are more difficult, especially in the smaller

femoral and popliteal arteries. The distortion produced by multiple incisions which would be necessary to remove these blocks can to some extent be reduced by the use of an instrument which strips the block with only two incisions in the artery. A further use of disobliteration lies in the removal of emboli which have been allowed to remain *in situ* for longer than one could wish and yet the limb has survived with a minimum of circulation.

The second method of obtaining a good pulsating flow is by arterial replacement. This seems a better term than grafting, since even when human tissues are used they do not live. A great deal has been learnt about this method, which is now almost commonplace. In the periphery an end-to-end anastomosis is not so good as an end-to-side anastomosis with a broader suture line. The graft should be larger than the normal artery and should be inserted well above and below the diseased area. The commonest type of graft is common femoral to popliteal artery by-passing the superficial femoral block. The key point for success is usually whether the popliteal artery is in good enough condition to take the graft. Below this level it is only necessary to have one good artery to carry the blood to the foot. In the early days a homograft taken in the post-mortem room was the method of choice, and it is still widely used, but latterly there has been a definite change towards synthetic prostheses such as orlon and teflon. They are not only very much easier to obtain, but easier to use in some respects.

For an aneurysm a graft is essential. For a long block or widespread atherosclerosis a by-pass may well be the only method of saving the limb. In the treatment of patients with claudication it is certainly effective, but careful consideration is needed in these cases before it is used. The possibility of recurrent thrombosis has always to be borne in mind, and it is for this reason that most patients are given long-term treatment with anticoagulants. In spite of this hazard long grafts may be inserted with very gratifying results, as, for example, aortic bifurcation to popliteal artery.

CONCLUSION AND SUMMARY

To summarize, the position may be stated as follows: Patients with intermittent claudication require careful consideration as to whether the condition involves one leg or both legs, and whether they are retired or still earning their living; also whether or not they have healthy coronary arteries. From this group of patients some will be selected for disobliteration of a short block or stenosis. A few may be treated with a by-pass graft. For a further selected group there is the operation of tenotomy of the tendo Achillis. This is very effective providing one makes sure that claudication is not going to develop elsewhere and that there is no osteoarthritis of the knee-joint. It is best limited to one side only, although good results can be obtained when both tendons are divided.

For patients with ischaemia of the foot a lumbar sympathectomy may well be helpful, providing that unremitting rest pain is not present. If it is, then the only way to avoid amputation is a by-pass graft.

PLATE II

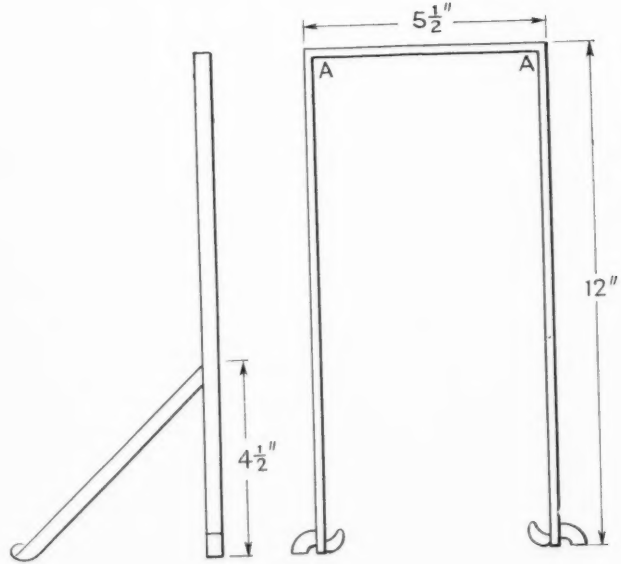

FIG. 1.—Showing the construction of the calliper locking device.

FIG. 2.—Application of the locking device.

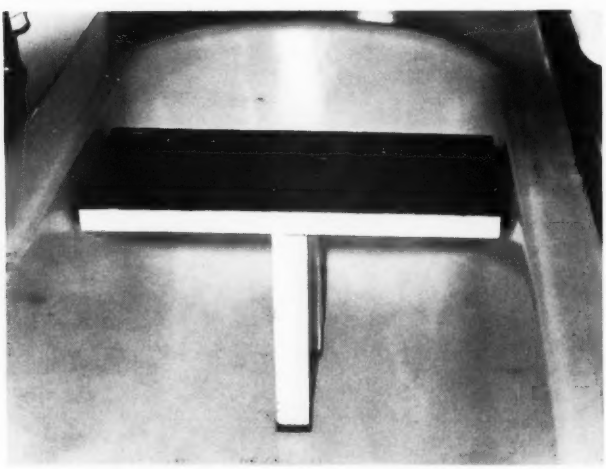

FIG. 3.—Showing the seat fixed in the bath.

NEW APPLIANCES

A LOCKING DEVICE FOR DOUBLE-IRON LONG-LEG CALLIPERS

A SIMPLE calliper locking device—the "calilock"—has been designed and made in the occupational therapy department of the Devonshire Royal Hospital. It was devised before the publication of a similar device—the "boomerang" leg-brace extension device—and, like it, enables knee locking in extension to be readily accomplished by those with spastic lower limbs or poor grip.

It consists of an upright handle with two curved feet, and two legs with inwardly curving feet fixed to the handle at an angle of 45 degrees (Plate II, Fig. 1). The material used was mild steel strip $\frac{1}{2} \times \frac{1}{8}$ inch; bending was facilitated by heating to red heat, and the feet and legs were welded in position. Minor variation of the angles at A may be needed to suit callipers of varying width.

The device is used as shown in Plate II, Fig. 2. It weighs $1\frac{1}{4}$ lb. The cost is negligible, the material being obtained from derelict wheel-chairs.

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A CHEAP AND RIGID BATH SEAT

MOST commercially produced bath seats are relatively expensive, and some do not give a heavy patient a feeling of security. The appliance here described is absolutely rigid; it is simple to make and the materials cost about 12s. 6d. The seat is composed of a length of planking, $9 \times 1\frac{1}{2}$ inches, cut 1 inch short of the width of the bath, and to each end of which are screwed three rubber studs. Two legs 2 inches square, cut to the appropriate length, are screwed and glued to the middle of the seat. Squares of sponge rubber are glued to the bottom ends, so that there is no marking of the sides or bottom of the bath. After the wood has been painted a piece of cork $\frac{1}{4}$ inch thick is cut to size and glued to the seat.

The appliance is wedged into the bath so that the central legs take the weight (Plate II, Fig. 3). This gives a completely rigid seat which will bear the heaviest person, and the wider seat (9 inches as compared with the average 7 inches) gives much more confidence.

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REVIEW SERIES

ELECTRODIAGNOSIS IN THE NEUROMUSCULAR DISORDERS OF CHILDHOOD

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THE clinical diagnosis of muscular hypotonia occurring in infants or young children can cause considerable difficulty. The condition may occur as one feature of a general disease (such as an acute specific fever or rickets), and here the symptom picture of the particular disease is clear, so that treatment and management are turned towards that direction. Where hypotonia is the presenting symptom, however, the position is far from clear, the reason being that many differing diseases can have similar natural histories and end-effects, so that the keystone of clinical diagnosis and differentiation is lacking. In consequence special techniques have to be applied to this problem.

CLINICAL PRESENTATION

Only those conditions in which hypotonia or allied phenomena are the presenting symptoms will be considered further. The parents may seek advice for any of the following: "floppiness" of the child or because it lies unnaturally still in its cot; delay in passing the usual motor milestones (supporting its own head at 3 months, sitting unsupported at 6 months, etc.); slowness and clumsiness in walking or, more rarely, loss of previous ability in motor skills. A febrile illness is often said to have been the immediate forerunner of these symptoms; this information is of no great help in determining the aetiology of the condition, sometimes being closely connected with the onset as in infantile polyneuritis, at other times being an incident in the course of the disease serving only to draw attention to the muscular abnormalities (e.g. a chest infection in Werdnig–Hoffmann's disease). Examination in early cases shows a limp child whose muscles feel soft and flaccid. The limbs can be moved about with unnatural ease, and in many cases the joints can be put through an abnormally large range of movements. The tendon reflexes are usually diminished and may be absent.

A broad classification of diseases presenting in one of these ways is as follows:

Group 1. Local causes:
Congenital dislocation of the hip
Congenital pes cavus

Group 2. Neurological disorders outside the lower motor neurone:
- Mental deficiency
- Cerebral palsy (atonic or flaccid stage)
- Hydrocephalus
- Freidreich's ataxia, Spina bifida } some lower motor neurone involvement also often present

Group 3. Disorders within the lower motor neurone/muscle-fibre system:
- Anterior poliomyelitis
- Charcot–Marie–Tooth disease
- Werdnig–Hoffmann's disease
- Infantile polyneuritis
- Myasthenia gravis
- Polymyositis
- Muscular dystrophies
- Arthrogryposis multiplex congenita

Groups 1 and 2 are by no means complete, but provide the commoner causes within each group: their clinical differentiation is beyond the scope of this article, and only Group 3 will be considered in greater detail.

Anterior Poliomyelitis

The sudden onset with lack of progression after the initial onslaught, together with the usually asymmetric limb and muscle group involvement, serves to differentiate this disease from others within the group.

Charcot–Marie–Tooth Disease

This condition has a strong familial incidence, though isolated cases do occur. Males are affected more often than females, and, the age of onset being usually in late childhood or early adolescence, cases before the age of 5 are most unusual. Symmetrical weakness and wasting of the small muscles of the feet and anterior compartment of the calf are the first signs; later the hands also become involved, but the process never involves the proximal parts of the limbs.

Werdnig–Hoffmann's Disease

The classical form of this disease begins in the second six months of life and has run to a fatal termination by 18 months. There is progressive generalized muscular weakness and wasting, though proximal limb muscles tend at first to be involved more than distal ones. The wasting may not be apparent, and the reduction in muscle bulk in these circumstances can be shown by soft-tissue radiographs. A helpful and usually constant clinical feature is the sparing of the diaphragm with involvement of the intercostal muscles, resulting in indrawing of the lower ribs and protrusion of the abdomen on inspiration.

Variants of the time-course of this disease may occur, the first symptoms appearing within the first few weeks or even days of life with very rapid deteriora-

tion. In other cases there is a much later onset (up to the age of 2) with a correspondingly slower deterioration. Very rarely the disease appears to become arrested or deterioration is so slow that it is difficult to assess. Needless to say, the child is severely disabled, but may reach the age of 12. Finally, there is some evidence (discussed under "Arthrogryposis Multiplex Congenita") that a similar disease process may occur in intrauterine life, becoming burnt out before birth.

Infantile Polyneuritis

A short febrile episode occurs associated with an infection of the upper respiratory tract or gastro-intestinal disturbances; when this has cleared the child is noticed to be less active than before. In severe cases paralysis of the limbs is evident, though frequently inactivity is overlooked or ignored for some time. The disease, if untreated, runs a variable course, proceeding rapidly to complete paralysis at worst; in most cases there is slow progressive deterioration, but occasionally it may become "burnt out", and recovery at least to some extent may occur. Diagnosis is confirmed by a raised level of protein in the cerebrospinal fluid in association with a normal cell count.

Myasthenia Gravis

This disease, rare in adults, is also only very occasionally seen in children. The patient's weakness is variable both in degree and in muscular distribution; this characteristic picture separates it from other diseases in this group.

Polymyositis

Again this is rarely seen in children, and it appears to lack the association with malignant disease which is present in adults. As with adults, however, it may be seen with or without involvement of the skin, and may be localized to affect few muscles only. Fever is usually present in the more severe cases, especially in dermatomyositis. In the milder cases the course is rather variable, with a distinct tendency to "burning-out" and spontaneous improvement. Pseudo-hypertrophy of affected muscles may occur, thus making clinical diagnosis difficult and unreliable, except after long-term observation.

Muscular Dystrophies

The clinical differentiation of this group is based largely on descriptive criteria such as involvement of characteristic muscle groups. The following are the main subdivisions of this group: Erb's juvenile type; facio-scapulo-humeral (Landouzy–Déjérine); ocular myopathy (very rare in children); pseudo-hypertrophic (Duchenne); atrophic (Batten); distal (Gowers); congenital varieties.

Erb's juvenile variety and facio-scapulo-humeral muscular dystrophy are described together and may be regarded as virtually identical. The muscles affected are confined to the upper arm, shoulder girdle, and face, and Erb's

variety is usually separated on the grounds that the face is not involved. The age of onset is very variable, from the age of 2 or 3 years up till 30. Either sex may be affected and there is usually a strong familial incidence, though isolated cases occur. There is a marked tendency for the disease process to arrest spontaneously.

Ocular myopathy may be regarded as a variant of the above, the extrinsic muscles of the eye being first affected. Ultimately the facial and neck muscles become slowly involved in a proportion of cases.

The other varieties mentioned have a generalized muscular distribution in the later stages of the disease, though proximal (pseudo-hypertrophic muscular dystrophy) or distal muscle weakness is first apparent at the onset.

Pseudo-hypertrophic muscular dystrophy is too well known to merit a detailed description; it is the most clear-cut of the dystrophies, the onset being usually between the ages of 3 and 6. There is a heavy preponderance of male cases with a strong familial incidence, and the slow relentless progression usually terminates fatally with an intercurrent infection in late childhood.

The atrophic and distal varieties are less well marked clinically, though the majority of cases fit fairly well into the description above, pseudo-hypertrophy being absent. However, there is a much greater range of variation in this group, the possible age of onset being as young as 6 months, and the course of the disease is much less predictable, varying between the extremes of rapid deterioration or periods of remission with apparent improvement. It should be emphasized, however, that either of these extremes is distinctly uncommon.

Congenital myopathies possibly occur more frequently than is realized; the condition is well substantiated in the literature (Turner, 1940, 1949), and, though most cases reported tend to be non-progressive, some are undoubtedly rapidly progressive (de Lange, 1937). The difficulty in making a clinical diagnosis in these latter cases needs no stressing.

Arthrogryposis Multiplex Congenita

Although flaccidity and floppiness have no part in the symptom picture of this disease—the joints being deformed and immovable—it is included in this article because it bears an interesting relationship to the foregoing. The muscles surrounding a joint involved in this disease show pathological changes, and indeed the argument can be advanced that the joint changes are secondary to muscle disease.

The muscle changes which have been reported in this condition have been those of denervation atrophy (Adams *et al.*, 1953) or of myopathy (Banker *et al.*, 1957), so that no constant aetiological factor (except non-specific muscle weakness) is present. Furthermore, in some of these cases of denervation atrophy post-mortem examination of the spinal cord has revealed considerable reduction in the numbers of anterior horn cells, unfortunately without definite evidence whether this has been caused by a degenerative process or a failure of development.

Amyotonia Congenita

From the above it can be seen that many differing conditions may cause the picture of "hypotonia at or soon after birth, improving slowly to partial or even complete recovery". This is the original description of amyotonia congenita given by Oppenheim (1900), and it is a debatable point whether or not this is a specific clinical entity entitled to a separate name. In the past the term was used indiscriminately, and Walton (1956) introduced the term "benign congenital hypotonia" in an attempt to reduce the confusion surrounding the older term. However, no distinct pathological finding has yet been established and there has been lack of agreement between pathologists on the use of the term, some using it for cases shown histologically to be either neuropathic or myopathic, while others (Greenfield and Stern, 1927) have regarded amyotonia congenita as being identical with Werdnig–Hoffmann's disease. Clinically the position is no clearer, polymyositis, polyneuritis, congenital and early myopathies, and possibly rare variants of Werdnig–Hoffmann's disease all being able to cause this similar picture. The question of improvement in a hypotonic child can be most difficult to assess unless the disease process either stops dramatically or progresses rapidly; the clinical progress is the resultant of two opposing forces—the disease process on the one hand and the natural development of skills by the growing child on the other. Personal assessment is necessary, the parents of handicapped children being only too anxious to claim improvement where none really exists. Clearly the situation with regard to amyotonia congenita or equivalent terms is unsatisfactory, and it will remain so until either a basic functional or pathological lesion is established.

METHODS OF INVESTIGATION

1. Biochemical

Little help can be gained so far by biochemical tests; the serum aldolase level is raised in any condition in which there is a breakdown of muscle constituents; there is probably insufficient differentiation between neurogenic and myogenic atrophy. This differentiation may be obtained, however, by finding a reduced or normal 24-hour excretion of creatinine with a concomitantly raised excretion of creatine. This finding is characteristic of muscular dystrophy and polymyositis, but it is by no means a constant occurrence.

2. Histological

The unreliability of conventional methods of staining muscle biopsy material has bedevilled the study of this group of diseases. In particular, the terminal nerve fibres are not stained by these methods, so that interpretation as to whether degeneration is occurring in individual muscle fibres (as in myopathies) or in motor unit blocks (as in neurogenic atrophies) is made hazardous.

Newer methods stain not only the terminal nerve fibres but also the end-plate itself, thus giving a much more accurate picture. These methods are technically difficult, and it seems likely that they will be available only in specialized centres. For a full account of the details and results of these techniques reference should be made to Coers and Woolf (1959).

3. Electrodiagnosis

Technique

An up-to-date account of the methods of electrodiagnostic investigations into the lower motor neurone/muscle-fibre disorders in adults has already been given in this series (Richardson and Wynn Parry, 1957). With children the standard techniques need modification; strength–duration curves are of little practical value, because of the lack of co-operation and low pain threshold of the patients, and when their use is absolutely necessary they are best performed under general anaesthesia. In practice, therefore, electromyography is performed first, and in the large majority of cases a definite result can be obtained. Surface electrodes, unfortunately, are not suitable for diagnostic purposes, so that coaxial needle electrodes of standard pattern have to be used. Naturally, the minimum number of muscles necessary for a diagnosis are tested, and by experience it has been found that tibialis anterior is the muscle of choice for first testing. This is so for several reasons: the lower limb is more often the site of symptoms than the upper; tibialis anterior is involved early in polyneuritis and Werdnig–Hoffmann's disease; the normal range of duration and amplitude of motor-unit potentials does not vary much from the accepted standard of 5–7 msec. and $\frac{1}{3}$–1 mV; polyphasic forms are seen only rarely in the normal; and maximal contraction can be obtained in the infant or uncooperative child by tickling the feet. If the results in this muscle are normal and a myopathy is suspected, then a girdle muscle should also be tested; myographically the vastus medialis is ideal for this purpose, because it normally has very few short-duration potentials, but it is usually difficult to obtain a sustained contraction. The deltoid is more easy in this latter respect, but suffers from the disadvantage that normally patches of short-duration small potentials may be obtained. Admittedly these are few and far between, but nevertheless must raise suspicion of an early myopathy. Also it must be appreciated that the leisurely and systematic search which is possible in adults is not usually attained in children.

Interpretation

The abnormal patterns obtained are exactly those of adult disorders (for a detailed description see Richardson and Wynn Parry, 1957) with a few minor variations. By electromyography the anatomical site of the lesion may be localized to the anterior horn cell, the peripheral nerve fibre, or the muscle fibre. In terms of floppy children these methods differentiate between Werdnig–Hoffmann's

disease, infantile polyneuritis, and the myopathies, the last being further subdivided into neuromyositis and muscular dystrophy, depending on the presence or absence of signs of denervation.

a. *Werdnig–Hoffmann's Disease.*—Large ($1\frac{1}{2}$–3 mV), long (10–15 msec.) polyphasic units with a reduced interference pattern; fibrillation potentials are not always found; fasciculation potentials have not so far been described. These findings are the most clear-cut of any group and have virtually 100% correlation with clinical and post-mortem results. The presence or absence of fibrillation potentials seems to have no significance in prognosis, this latter depending on the age of onset—the earlier the onset after birth the more rapid the course of the disease.

b. *Infantile Polyneuritis.*—Fibrillation potentials are usually present at rest and a full search is justified; should there be doubt about the presence of denervation and fibrillation is not found, then a strength–duration curve under anaesthesia is indicated. The motor-unit pattern is of normal duration and shape, sometimes increased in amplitude, with a diminished interference pattern. Obviously a reduced interference pattern may be due to lack of maximum volitional effort, so that every effort should be made to achieve even a short burst of maximal contraction. It is because of this element of doubt that corroborative evidence of denervation is much more important than in Werdnig–Hoffmann's disease. This lack of volitional effort is seen especially in mental deficiencies and cerebral palsy; hypotonia is a marked feature in mongolism, and in a mixed group of ten such children examined with Dr. D. H. H. Thomas at Cell Barnes Hospital, St. Albans, a slight reduction in the interference pattern was the only myographic abnormality.

Finally there remain a very small group of patients who have a marked reduction of functioning motor units so that only one or two motor-unit potentials may be recorded at any position in the muscle, and yet show no signs of denervation either myographically or in strength–duration curves. All the children who have been investigated so far have been seen late (two or more years after onset), and a critical account of the first six months of life has not been obtained. Theoretically the explanation may be either (1) failure of development of the lower motor neurone system, or (2) a denervating process either before or soon after birth which has burnt out, the denervated muscle becoming fibrotic. A third possibility also exists (shown by a small series of six patients, both children and adults—Campbell, 1961) in that, contrary to all expectations, a myopathy (muscular dystrophy or polymyositis) may produce single discrete normal units in the absence of a disintegrated pattern within that particular muscle. Needless to say, in each case it was established beyond all doubt that the diagnosis of myopathy was correct; three of these cases have been mentioned briefly by Heathfield and Williams (1960). One feature common to all was that the disease had been present for some time.

c. *Myopathies.*—The presence of disintegrated motor-unit potentials of small amplitude is the hall-mark of the myopathies. In uncomplicated muscular dystrophies no case has as yet been reported where signs of denervation have been shown, and the coexistence of either abnormal strength–duration curves or fibrillation together with disintegrated motor units is interpreted as due to polymyositis (or, more correctly, neuromyositis). Fibrillary after-discharge and high-frequency discharges may be heard occasionally in either muscular dystrophies or polymyositis and are thought to signify the presence of active degeneration.

The diagnosis of an established myopathy causes no difficulty, but the interpretation of a few small patches of disintegrated units on minimal volition calls for the greatest care, and it seems justified to err on the side of reporting doubtful cases as normal rather than as myopathies, for once this diagnosis is given there is a regrettable, though natural, tendency for interest in the case to cease. Frequency analysis has been of no help in the problem, the ear being of sufficient sensitivity for the purpose. Interpretation has to be made on the following rather vague criteria:

1. The numbers of short-duration small potentials which can be accepted as normal for each particular muscle (i.e. very occasional ones in tibialis anterior and vastus medialis, rather more in deltoid, and very many in extensors of wrist and fingers).

2. The extent of the "patch" encountered, as judged when moving the needle through the muscle.

3. The persistence of short or disintegrated potentials as the interference pattern is built up.

CONCLUSION

Over 250 patients have been tested with the above techniques at the Hospital for Sick Children, Great Ormond Street, since 1954, and the results obtained compare favourably with those of other methods of diagnosis. The main difficulty in making a comparison is that there is no final arbiter of correctness. Nevertheless, electrodiagnosis has been carefully worked out in adults, and it seems reasonable to transfer this experience into the field of childhood disorders. The main errors and limitations of the methods lie in the diagnosis of myopathies, as has already been described, and further advances of technique are needed in this connexion.

Analysis of the results both *in toto* and on a yearly basis shows remarkably constant features: about one-half of the patients referred have normal electrical findings, thus suggesting that the cause of the hypotonia is outside the lower motor neurone system. Of the half remaining, roughly one-third have signs of Werdnig–Hoffmann's disease, one-third polyneuritis, and one-third myopathies.

No typical electrodiagnostic pattern has been found for amyotonia congenita, and it is possible that the defect in this condition (if it exists at all as a separate

entity) will be found in the sensory side of the reflex arc or in some abnormality of muscle-spindle function.

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I wish to thank Dr. Basil Kiernander and Dr. A. T. Richardson for their constant help and advice.

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REVIEWS OF BOOKS

ARTHRITIS AND ALLIED CONDITIONS: A TEXTBOOK OF RHEUMATOLOGY. Edited by J. L. Hollander and Collaborators. *Sixth edition. Pp. 1306. 150s. London: Kimpton. 1960.*

In this, the sixth edition of an already well-known book, the editor and his collaborators have performed the feat of adding 19 new chapters and bringing other chapters up to date, yet only increasing the number of pages by just over 200.

The need for revision and addition of so much new material reflects the tremendous surge of interest and research in the rheumatic diseases, which was triggered off by the discovery of the action of steroid drugs in rheumatoid arthritis in 1948; it is a matter for regret that so much of the new material has perforce to remain speculative and controversial. As would be expected, the new chapters include, among others, some reflections on the significance of the rheumatoid factor, immunological considerations, and the concept of the collagen diseases.

The text is clear and readable, and summaries in box form for quick reference appear at the end of most chapters. The illustrations are of a very high standard and numerous, and the bibliography is extensive. The contents are remarkably complete, covering not only the relatively small field of the rheumatic diseases, but also a great deal of general medicine as well.

This book is by no means cheap, but it is so complete and beautifully produced that it is difficult to see how it could be published at lower cost. It remains the only textbook of unquestioned authority in the English language on the rheumatic diseases. No one engaged in the management of this group of diseases can afford not to have it as a reference book.

A. C. BOYLE

THE DEMAND FOR MEDICAL CARE. By Gordon Forsyth and Robert F. L. Logan. *Pp. 154. 7s. 6d. London: Oxford University Press for Nuffield Provincial Hospitals Trust. 1960.*

This is the report of a survey, undertaken on behalf of the Nuffield Hospitals Trust, of the need for hospital beds in relation to the size of population in an industrial area—Barrow-in-Furness. With beds in new hospitals costing £5,000 each, compared with £1,500 for a council house, it is obviously important to assess the need for such beds before building new hospitals.

The authors conclude from their survey that the demand for acute hospital care can be satisfied with about 250 beds per 100,000 of the population, or half that thought necessary at the start of the National Health Service. They believe that hospital and specialist services should be recognized as being only supplementary to the general medical care provided by general practitioners, supported by domiciliary services. In fact, they found that the hospital is still the central point of focus of the Health Service, and conclude that too many patients spend too long in hospital beds, which are becoming increasingly expensive.

This book certainly challenges the present concepts of a health service, and in particular of the role of hospitals in it. It should certainly be read by those doctors who work in hospitals, for its conclusions may well form the basis for the future development of the hospital service.

S. MATTINGLY

ELONGATION TREATMENT OF LOW BACK PAIN. By George H. Hassard and Charles L. Redd. *Pp. 78. 36s. Springfield, Illinois: Thomas. 1959.*

The authors apparently believe that low back pain and other musculo-skeletal disorders are due to contractures of fibrous tissue in ligaments and fascial sheaths; these contracted structures compress and irritate adjacent peripheral nerves, causing local and referred pain. No evidence is offered for this theory, but then this book is not really written for doctors, but for physiotherapists, nurses, and lay business executives. This accounts for the fact that much of the book is taken up with definitions of medical terms and anatomical diagrams. Less than twenty pages are devoted to treatment, and only six of these describe the specific treatment advocated. Moreover, consideration of conditions affecting the neck and upper limbs seems out of place in view of the title of this book. Apart from these general criticisms, many doctors in Britain will view with concern the suggestion that the physiotherapist should make the diagnosis and treat the patient, only referring him to a doctor if treatment is unsuccessful.

S. MATTINGLY

REHABILITATION OF HAND FUNCTION. By A. N. Leont'ev and A. V. Zaporozhets. Translated from the Russian by Basil Haigh and edited by W. Ritchie Russell. *Pp. 199. 60s. London: Pergamon Press. 1960.*

This is an interesting book. It is an attempt to place on a scientific footing the techniques used to restore power, range of movement, co-ordination, and sensation after injuries of the upper limb, and is not exclusively confined to the hand.

Most of the book is concerned with occupational therapy; little is said of exercise techniques or physiotherapy, trick movements are scantily treated, and lively splints not mentioned. To this extent the title belies the contents, as the book covers only one, albeit extremely important, aspect of rehabilitation. Some ingenious experiments are fully described in which the movements involved in various crafts, particularly carpentry, and the change in movement patterns with recovery are analysed mechanically. There are many sensible remarks on the psychology of rehabilitation, and useful comprehensive tables of the specific indications for each type of occupational therapy for individual disabilities at all stages.

It is unfortunate that the style of writing is involved and often difficult to follow, and there are many obscurities in the description of theories of movement patterns and their co-ordination. The text is not in letterpress and the illustrations are line drawings, not photographs of actual patients. This was deliberately done by the publishers in order to accelerate publication and keep down the cost.

It is, however, fascinating to learn of the efforts of rehabilitation centres behind the Iron Curtain, and how closely they agree with Western ideas. But the book is worth close study for the chapters on re-education of sensation and gnostic sensibility. A real effort has been made, with remarkable success, to re-educate tactile sensation in patients, both sighted and blind, with sensory loss and amputations. The techniques used are simple, logical, and highly practical. This aspect is all too often overlooked in Britain, and the erroneous attitude adopted that only crude sensation can be expected after neurotmesis. For this contribution alone the authors deserve high praise.

C. B. WYNN PARRY

ABSTRACTS OF THE LITERATURE

The Entrance of Glucose and Other Sugars into Joints. M. W. ROPES, A. F. MULLER, and W. BAUER. *Arthr. and Rheum.*, 1960, **3**, 496.

The transfer of various substances, especially glucose, across the blood–synovial-fluid barrier was investigated in health and disease. The mechanism is important, because cartilage, being avascular, relies mainly on synovial fluid for nutrition. It was found that the glucose content of the blood and synovial fluid was approximately the same in health and in mild inflammatory states, but is greatly reduced in the synovial fluid in severe inflammation. When the blood glucose level was rapidly raised there was a marked lag in rise in the synovial fluid; the cause of this was not obvious, and it did not occur with other substances.

M. HOLROYD

The Vascular Pattern of the Anterior Muscles of the Forearm in Adults in Relation to Volkmann's Ischaemic Contracture. V. BONI. *Postgrad. med. J.*, 1960, **36**, 668.

Working at the Nuffield Orthopaedic Centre, Oxford, the author has demonstrated significant differences in the blood-supply of the muscles in the anterior compartment of the forearm. The technique used was that of intra-arterial injection of barium suspension into cadaveric arms followed by radiography and dissection. Forearm muscles, he finds, may be grouped into those with blood-supply from one artery only, those from two arteries, and those from more than two. The muscles in the first two groups are those most likely to develop Volkmann's contracture.

FRANCIS ANDREWS

The Morbid Anatomy of Cervical Spondylosis and Myelopathy. M. WILKINSON. *Brain*, 1960, **83**, 589.

In 17 patients with cervical spondylosis autopsies were carried out and the spinal cords, roots, vertebrae, and disks examined. There are two main types of disk protrusion—nuclear herniation, in which a traumatic tear of the annulus occurs and nuclear material is extruded; and annular protrusion, which is commoner and occurs in the middle-aged and elderly. The disk loses elasticity and collapses and the annulus bulges. If it bulges centrally the resulting lesion is cord compression; if laterally, root compression; or there may be a combination of both. This in turn leads to osteophyte formation, sclerosis of vertebral bodies, and subluxation of corresponding intervertebral joints.

Of the 17 patients, 12 had flattening and distortion of the cord corresponding to the distribution and size of the bosses and bars on the posterior aspect of the vertebral column. There was no vascular disorder, and it was not felt that thrombosis of the anterior spinal artery plays a part in these disorders. The spinal cord is particularly liable to damage as a result of injury to the spondylitic spine.

C. B. WYNN PARRY

Rheumatoid Arthritis. *Med. Wld (Lond.)*, 1961, **94**, 27.

This clinical memorandum beautifully expounds the principles of drug therapy in rheumatoid arthritis and is just the sort of guide to give junior doctors taking up physical medicine. It would serve as an excellent model answer in the Membership or Diploma examinations.

C. B. WYNN PARRY

Cervical Vertebral Erosions and Subluxations in Rheumatoid Arthritis and Ankylosing Spondylitis. W. MARTEL and J. W. PAGE. *Arthr. and Rheum.*, 1960, **3**, 546.

The authors found many instances of atlanto-axial or lower cervical subluxation and odontoid process erosions in long-standing severe cases of rheumatoid arthritis and ankylosing spondylitis. In cases of persistent neck pain lateral radiographs in extension and flexion are invaluable, and occasionally laminograms may also be useful. Vertical translation of the cervical spine and at times true basilar invagination may be found. The slow development of these lesions and the greatly decreased neck flexion are thought to account for the paucity of serious neurological findings. The relationship between rheumatoid arthritis and ankylosing spondylitis is emphasized.

M. HOLROYD

Acute Suppurative Arthritis: Diagnosis and Therapy. J. WARD, A. S. COHEN, and W. BAUER. *Arthr. and Rheum.*, 1960, **3**, 522.

Acute suppurative arthritis is usually monarticular, and rheumatoid arthritis, gout, or rheumatic fever may be suspect. The condition may be superimposed upon existing joint disease, and here steroid therapy can mask the true picture. Aspiration, which is an important diagnostic procedure, shows a

marked polymorphonuclear leucocytosis and low glucose content. Symptoms are those of any acute local infection. Treatment with antibiotics, repeated aspiration, and physiotherapy to ensure joint movement provide the basis for excellent recovery.

M. HOLROYD

Psoriatic Arthritis: A Roentgenologic Study. R. AVILA, D. G. PUGH, C. H. SLOCUMB, and R. K. WINKELMANN. *Radiology*, 1960, **75**, 691.

The radiographs of 155 cases of psoriasis and arthritis were compared with those of 100 cases of rheumatoid arthritis. Five signs are suggested as the X-ray criteria for the diagnosis of psoriatic arthritis. On these criteria 48 (31%) of the 155 cases could be classified as of psoriatic arthritis. An equal number of cases (48, or 31%) had some manifestation of psoriatic arthritis plus those of rheumatoid arthritis, while 58 cases (38%) had signs of rheumatoid arthritis only.

The authors conclude that, "while psoriatic arthritis is a destructive arthritis typical of psoriasis, rheumatoid arthritis also is often associated with that disease".

G. O. STOREY

Changes in Nerve Conduction with Ulnar Lesions at the Elbow. R. W. GILLIATT and P. K. THOMAS. *J. Neurol. Neurosurg. Psychiat.*, 1960, **23**, 312.

Following the excellent series of papers by these authors on conduction studies on peripheral nerves, this paper describes techniques for localizing the lesion in ulnar neuritis at the elbow. In addition to the conventional motor-conduction studies, techniques are described for recording sensory action potentials in the axilla on nerve stimulation above the elbow. These are normal in such patients, while no sensory potentials can be recorded from the elbow on stimulation at the wrist, or from the wrist when the little finger is stimulated.

C. B. WYNN PARRY

Parageusia Following Bell's Palsy: A Result of Faulty Reinnervation. G. RUSHWORTH. *J. Neurol. Neurosurg. Psychiat.*, 1960, **23**, 250.

This interesting short paper describes the case of a woman of 75 who sustained a Bell's palsy and in whom persistent parageusia (salty taste) developed seven months later. This was not abolished by local anaesthesia of the mouth, but facial-nerve block was successful in clearing up the condition. The author suggests that there was faulty reinnervation of proprioceptors with taste fibres of the chorda tympani.

C. B. WYNN PARRY

Nerve Fibre Degeneration in the Brain in Amyotrophic Lateral Sclerosis. M. C. SMITH. *J. Neurol. Neurosurg. Psychiat.*, 1960, **23**, 269.

In seven cases of amyotrophic lateral sclerosis degeneration in corticospinal tracts at all levels was found. The degenerating fibres were seen in the precentral gyrus, postcentral gyrus, corpus callosum, thalamus, reticular formation, substantia nigra, and tegmentum.

C. B. WYNN PARRY

Myositis Ossificans Progressiva. N. H. HARRIS. *Proc. roy. Soc. Med.*, 1961, **54**, 70.

An Adult Case of Chondro-osteodystrophy. L. KLENERMAN. *Proc. roy. Soc. Med.*, 1961, **54**, 71.

These are two case reports, well illustrated, of rare but important diseases. The first describes the beneficial effect of removal of bony plaques followed by X-irradiation in myositis ossificans progressiva, while the second describes a case of Morquio's disease associated with multiple loose bodies in several joints—a combination not previously reported.

C. B. WYNN PARRY

Peptic Ulcer Associated with Corticosteroid Therapy: Serial Roentgenographic Studies. J. G. BULGRIN, E. L. DUBOIS, and G. JACOBSON. *Radiol.*, 1960, **75**, 712.

A series of 77 patients from a collagen disease clinic were studied—70 with systemic lupus erythematosus, 3 with rheumatoid arthritis, and 4 with other collagen diseases. More than three-quarters of the patients were females. Steroid therapy was given to 63 of the 77 patients, the median daily dose being as follows: prednisone and prednisolone 40 mg., methylprednisolone 60 mg., triamcinolone 40 mg., and dexamethazone 10·7 mg.

A 27% incidence of peptic ulcer was found, gastric predominating over duodenal ulcer. There was a correlation between steroid dosage and ulcer incidence, and to a lesser extent length of treatment was a factor; but there was no variation in the effect of individual steroids. The behaviour of ulcers associated with steroid therapy was unpredictable; healing was the rule, but was delayed. Gastro-intestinal symptoms almost invariably accompanied the ulcer.

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